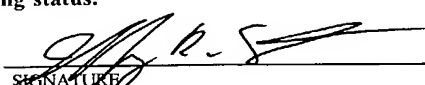
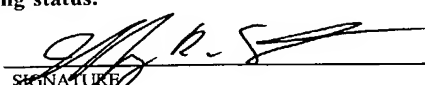


FORM PTO-1390 (REV. 12-2001) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 32226.19
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/089531
INTERNATIONAL APPLICATION NO. PCT/DE00/03293	INTERNATIONAL FILING DATE 21 September 2000	PRIORITY DATE CLAIMED 28 September 1999
TITLE OF INVENTION Mehrwertiger Magnetoresistiver Schreib/Lese-Speicher sowie Verfahren zum Beschreiben einer solchen Speichers		
APPLICANT(S) FOR DO/EO/US Infineon Technologies AG		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371. 2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371. 3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. <input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31). 5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau). b. <input checked="" type="checkbox"/> has been communicated by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US). 6. <input checked="" type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. <input checked="" type="checkbox"/> is attached hereto. b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4). 7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau). b. <input checked="" type="checkbox"/> have been communicated by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input checked="" type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)). 9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. <input checked="" type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).		
Items 11 to 20 below concern document(s) or information included:		
11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input type="checkbox"/> A FIRST preliminary amendment. 14. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment. 15. <input type="checkbox"/> A substitute specification. 16. <input type="checkbox"/> A change of power of attorney and/or address letter. 17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825. 18. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4). 19. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4). 20. <input type="checkbox"/> Other items or information:		

U.S. APPLICATION NO. (if known) 107-089531		INTERNATIONAL APPLICATION NO. PCT/DE00/03293		ATTORNEY'S DOCKET NUMBER 32226.19	
21. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$740.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS - PTO USE ONLY	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$ 130	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	17 - 20 =	0	x \$18.00	\$	0
Independent claims	2 - 3 =	0	x \$84.00	\$	0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ \$280.00	\$
TOTAL OF ABOVE CALCULATIONS =				\$	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				+	\$
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$	1,020
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$	
TOTAL FEES ENCLOSED =				\$	1,020
				Amount to be refunded:	\$
				charged:	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$ 1,020 to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-3732A duplicate copy of this sheet is enclosed. d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.					
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				SIGNATURE  Jeffrey R. Stone NAME 47,976 REGISTRATION NUMBER	

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SIGNATURE

Jeffrey R. Stone
 NAME
47,976
 REGISTRATION NUMBER

JC13 Rec'd PCT/PTO 27 MAR 2002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Re:	U.S. National Filing under)	
	35 U.S.C. §371 of International)	
	Application No. PCT/DE00/03293)	PATENT
)	
German Title:	Mehrwertiger Magnetoresistiver)	
	Schreib/Lese-Speicher sowie Verfahren)	
	zum Beschreiben eines solchen Speichers)	
)	
English Translation:	Multivalued Magnetoresistive Read/Write)	
	Memory and Method of Writing to and)	
	Reading from Such a Memory)	
)	
Applicant:	Infineon Technologies, AG)	
)	
Inventors:	Thewes, Roland		
	Schwarzl, Siegfried		
	Weber, Werner		

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

PRELIMINARY AMENDMENT

In the above-entitled patent application, please amend the application as follows:

In the Claims

Please amend Claim No. 1 as follows:

- 1 1. (amended) A magnetoresistive read/write memory, with a plurality of
- 2 multivalued storage cells [(11)], each storage cell [(11)] having two intersecting electric
- 3 conductors [(12, 13)] and a layer system comprising magnetic layers located at the
- 4 intersection of [the] said electric conductors [(12, 13)], wherein [the] said layer system is
- 5 designed as a multilayer system [(30; 40)] with two or more magnetic layers [(31, 32;
- 6 41-45)], at least two, but a maximum of all [the] said magnetic layers [(31, 32; 41-45)]
- 7 hav[ing] a magnetization direction [(33, 34; 46-50)] that can be set independently of one
- 8 another, [the] said magnetization direction [(33, 34; 46-50)] in [the] said individual layers
- 9 [(31, 32; 41-45)] [is] being changed [or can be changed] by the electric current flowing

10 through [the] said electric conductors [(12, 13)], and further comprising in each case a tunnel
 11 dielectric [(35;51) is provided] between two adjacent magnetic layers [(31, 32; 41-46)].

Please amend claim 2 as follows:

1 2. (amended) The magnetoresistive read/write memory as claimed in claim 1, in
 2 which [the] said magnetization directions [(33, 34; 46-50)] that can be set independently of
 3 one another in [the] said individual layers [(31, 32; 41-45) are set or] can be set via different
 4 current intensities.

Please amend claim 3 as follows:

1 3. (amended) The magnetoresistive read/write memory as claimed in claim 1 [or
 2 2], in which [the] said electric conductors [(12, 13)] are designed for high current densities.

Please amend claim 4 as follows:

1 4. (amended) The magnetoresistive read/write memory as claimed in [one of]
 2 claim[s] 1 [to 3], in which [the] said magnetic layers [(31, 32; 41-45)] are formed from a
 3 ferromagnetic material.

Please amend claim 5 as follows:

1 5. (amended) The magnetoresistive read/write memory as claimed in [one of]
 2 claim[s] 1 [to 4], in which [the] said intersecting conductors [(12, 13)] are aligned
 3 orthogonally to one another.

Please amend claim 6 as follows:

- 1 6. (amended) The magnetoresistive read/write memory as claimed in [one of]
2 claim[s] 1 [to 5], in which [the] said tunnel dielectric has a thickness of 2 to 3 nm.

Please amend claim 7 as follows:

- 1 7. (amended) A method of writing to a magnetoresistive read/write memory as
2 claimed in [one of]claim[s] 1 [to 6], having the following steps:
- 3 a) impressing a variable electric current into [the] said two electric conductors
4 and, as a result, producing a magnetic field;
- 5 b) setting [the] said magnetization direction in [the] said individual magnetic
6 layers of [the] said multilayer system via the field strength of [the] said
7 magnetic field produced, [the] said magnetization directions in [the] said
8 individual layers being set independently of one another via respectively
9 differently high requisite field strengths, in such a way that [the] said
10 magnetization directions are set first in those layers which need the highest
11 field strength for this purpose and that [the] said magnetization directions are
12 then set in those layers which respectively need a lower field strength for this
13 purpose.

Please amend claim 8 as follows:

- 1 8. (amended) The method as claimed in claim 7, in which [the] said different
2 field strengths acting on [the] said layers are produced by currents of different magnitudes
3 being impressed into [the] said conductors.

Please amend claim 9 as follows:

- 1 9. (amended) The method as claimed in claim 7 [or 8], in which [the] said
2 different field strengths acting on [the] said layers are produced by means of a different
3 physical spacing of [the] said layers in relation to [the] said conductors.

Please amend claim 10 as follows:

- 1 10. (amended) The method as claimed in [one of] claim[s] 7 [to 9], in which the
2 setting of [the] said magnetization directions in [the] said layers on the basis of field strengths
3 of different magnitudes are influenced by the layer material and/or the layer thickness and/or
4 the layer morphology.

Please amend claim 11 as follows:

- 1 11. (amended) A method of reading from a magnetoresistive read/write memory
2 as claimed in [one of] claim[s] 1 [to 6], having the following steps:
3 a) impressing a defined item of data into [the] said individual layers of [the] said
4 multilayer system in such a way that the item of data is first impressed into
5 that layer which needs the lowest field strength to set [the] said magnetization
6 direction, and that the item of data is then impressed into [the] said layers
7 having the respectively next higher requisite field strength; and
8 b) detecting a possible information change in [the] said layer or [the] said layers
9 on the basis of [the] said impressed defined item of data.

Please amend claim 12 as follows:

- 1 12. (amended) The method as claimed in claim 11, in which the detection of a
2 possible information change in [the] said layer or [the] said layers is carried out by measuring
3 the electrical resistance.

Please amend claim 13 as follows:

- 1 13. (amended) The method as claimed in claim 11 [or 12], in which the detection
2 of a possible information change in [the] said layer or [the] said layers is carried out via
3 detection of current and/or voltage pulses.

Please amend claim 14 as follows:

- 1 14. (amended) The method as claimed in [one of] claim[s] 11 [to 13], in which the
2 detection of a possible information change in [the] said layer or [the] said layers is carried out
3 before and after [the] said impression and/or during [the] said impression of [the] said
4 specific item of data into [the] said layer or [the] said layers.

Please amend claim 15 as follows:

- 1 15. (amended) The method as claimed in [one of] claim[s] 11 [to 14], in which
2 [an] said item of data with respectively the same value is successively impressed into all [the]
3 said layers.

Please amend claim 16 as follows:

- 1 16. (amended) The method as claimed in [one of] claim[s] 11 [to 14], in which
 2 [an] said item of data which belongs to an alternating algorithm is impressed successively
 3 into [the] said layers.

Please amend claim 17 as follows:

- 1 17. (amended) The method as claimed in [one of] claim[s] 11 [to 16], in which the
 2 results during [the] said detection of a possible information change for each layer are
 3 intermediately stored, at least temporarily, in a storage device.


Remarks

The purpose of this Preliminary Amendment is to conform to United States Patent and Trademark Office practice and not for the purpose of patentability. No new matter has been added by way of this Preliminary Amendment.

Respectfully submitted,
 INFINEON TECHNOLOGIES, AG

By its attorneys

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PCT/DE00/03293

MULTIVALUE MAGNETORESISTIVE READ/WRITE MEMORY AND
METHOD OF WRITING TO AND READING FROM SUCH A MEMORY

5 The present invention relates firstly to a
magnetoresistive read/write memory according to the
preamble of patent claim 1. Furthermore, the invention
relates to a method of writing to such a memory
according to the preamble of patent claim 7 and to a
10 method of reading from such a memory according to the
preamble of patent claim 11.

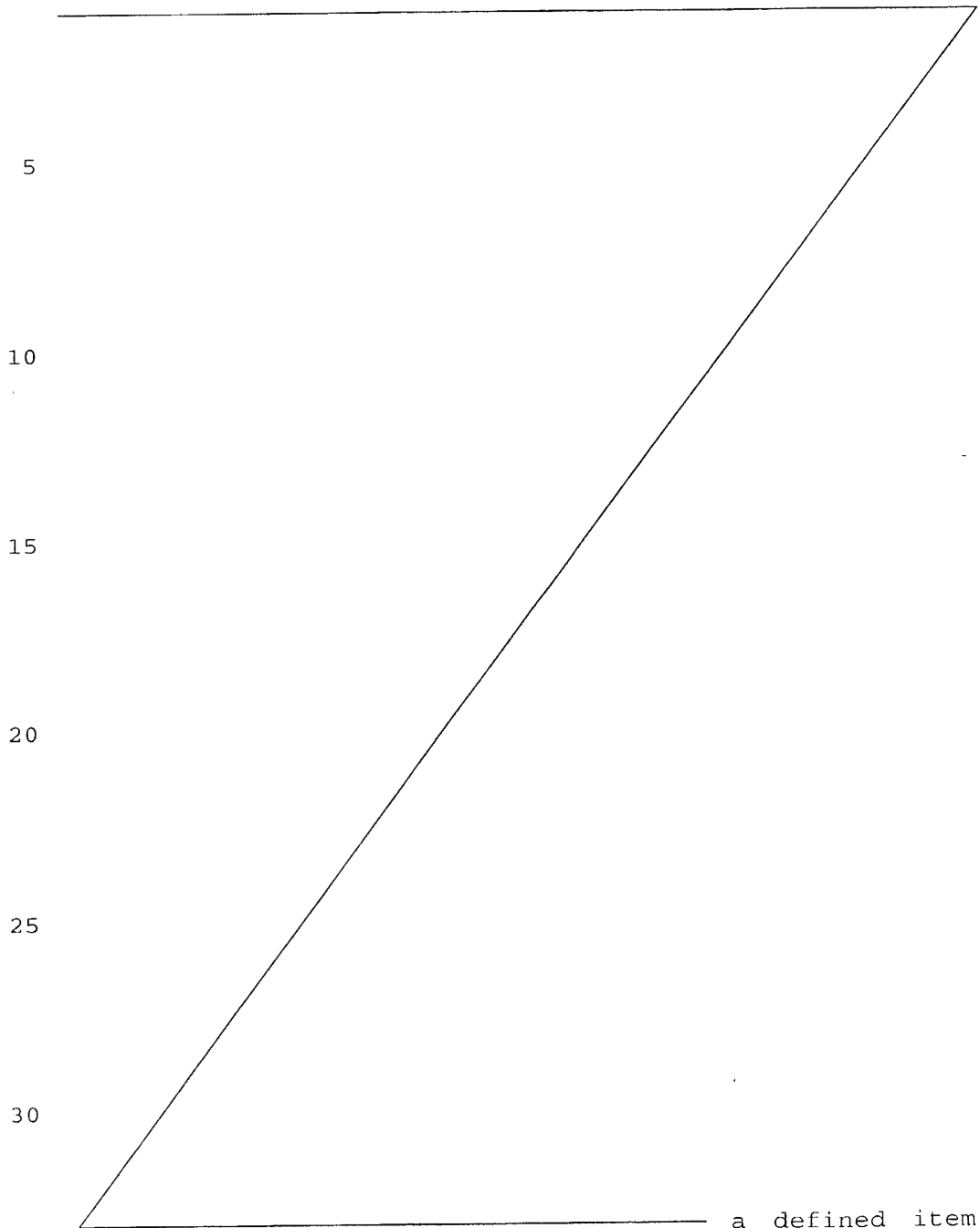
Magnetoresistive read/write memories, which are
referred to as MRAM memories (magnetoresistive random
access memory), are memories in which data can be
15 stored and also read again at one address. The memories
generally have one or more storage cells, the storage
effect residing in the magnetically variable electrical
resistance of the storage cell or the storage cells.

20 Hitherto the development concerned using single-value
storage cells, as they are known, with a binary storage
content for the magnetoresistive memories. These
storage cells comprise two intersecting electric
conductors, which are preferably aligned at right
25 angles to each other. At the intersection between these
conductors, there is a layer system comprising two
magnetic layers, one of the layers being formed from
soft magnetic material and the other layer from hard
magnetic material. Between the magnetic layers there is
30 a tunnel oxide. Such a storage cell is described in the
figure description in connection with fig. 1. Depending
on the state of magnetization, the magnetization
directions in the magnetic layers can be aligned in
parallel or antiparallel. Depending on the
magnetization direction in the magnetic layers, the
storage cell has a different electric resistance. In
this case, a parallel magnetization direction leads to
a lower electrical resistance of the storage cell,

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ART 34 AMDT

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of information is written to the memory cell. Depending
on whether the storage cell experiences a change in its
information content in the process, a current or
voltage pulse, or else the absence of such a pulse, can

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- 3 -

ART 34 ADDT

be detected on the corresponding read line. In this case, each read operation results in a loss of information from the cell. In order to compensate for this loss, the information read out is written back to the storage cell again after the read operation has been completed.

US-A-5,734,605 discloses a single-value MRAM storage cell in which two or more magnetic layers are arranged between two electric conductors. Because of ferromagnetic coupling between the magnetic layers, their magnetization directions are always oriented in parallel with each other in the absence of a magnetic field. The information stored in the storage cell is encoded in the direction of the common orientation of the magnetic layers. In order to read the information, a possible change in the electrical resistance of the layers, based on the large magnetoresistive effect, is detected by a magnetic field which is sufficient to fold over the magnetization direction of a first magnetic layer but is not sufficient to fold over the magnetization direction of a second magnetic layer being applied.

With regard to the problem of the increased area requirement of single-value storage cells in order to achieve powerful memory systems, in recent times multivalue storage concepts have been developed, but have hitherto been proposed only for other types of memories than MRAMs. Such a memory type is, for example, an EEPROM (electrically erasable PROM), which may be written to and erased electrically. In this case, specific subregions of a basically continuous value range are set equal to discrete states. Assignments of this type cannot be performed in the MRAM storage cells, since no storage of continuously variable information is possible. This is because, on the basis of their principle, MRAM storage cells

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ART 34 ANDT

- 3a -

fundamentally constitute a system with a finite number of discrete states. The approaches to multivalency with regard to the aforementioned EEPROMs cannot therefore be transferred to the magnetoresistive memories.

5

Jeong et al. (Jeong, WC, Lee, BI, Joo, SK (1998) "A New Multilayered Structure for Multilevel Magnetoresistive Random Access Memory (MRAM) cell", IEEE Transactions on Magnetism, US, IEEE Inc., New York, Vol. 34, No. 4, Part 01, pp. 1069-1071) have shown, by using a layer sequence of magnetic nickel-iron, nickel-iron/cobalt and cobalt layers, in each case separated from one another by a copper intermediate layer and formed on a silicon copper double layer, that because of different coercivity field strengths of the three magnetic layers, the magnetization directions of the magnetic layers can be folded over individually by means of applying a tuneable magnetic field. This phenomenon was measured by using a respectively abrupt change in the resistance of the layer sequence, detected by means of a four-point measurement, resulting from the large magnetoresistive effect. Furthermore, Jeong et al. propose to set the individual magnetization directions of the magnetic layers in a sequence beginning with the magnetic layer with the highest magnetic hardness down as far as that magnetic layer with the lowest electric hardness.

Also known with regard to multivalue structures is US-A-5,585,986, which discloses a digital magnetoresistive sensor for reading from a magnetic data storage system. This sensor has a multilayer structure, whose electrical resistance is measured. The multilayer structure comprises a number of ferromagnetic layers, the magnetic moments and therefore the magnetization directions of the individual layers being influenced by an external magnetic field, which is generated by the corresponding data carrier.

AMENDED SHEET

magnetic field strengths. In this way, the resistance of the sensor changes in graduated steps when the external magnetic field is varied, which produces a digital output signal.

5

On the basis of the aforementioned prior art, the intention is to provide a magnetoresistive read/write memory and a method of writing to and reading from such a memory in which the disadvantages and problems described in relation to the prior art are avoided. In particular, with regard to a possible saving of area, an improved MRAM memory and a suitable method of writing to and reading from such an MRAM memory are to be provided.

15

According to the first aspect of the invention, this object is achieved by a magnetoresistive read/write memory having one or more storage cells, each storage cell having two intersecting electric conductors and a layer system comprising magnetic layers located at the intersection of the electric conductors. According to the invention, the memory is characterized in that the layer system is designed as a multilayer system with two or more magnetic layers, in that at least two, but a maximum of all the magnetic layers have a magnetization direction that can be set independently of one another, and in that the magnetization direction in the individual layers is changed or can be changed on the basis of the electric current flowing through the electric conductors.

20
25
30

In this way, a multivalued memory having one or more multivalued storage cells and therefore with a correspondingly high storage capacity is created.

35

Furthermore, this memory or the at least one storage cell can be written to and/or read from in a simple way.

A fundamental feature of the memory according to the invention or of the storage cell or storage cells forming the memory consists in using an n-layer multilayer system with n greater or equal to two
5 magnetic layers at the intersection of the two electric conductors, it being possible for the magnetization direction in m layers, with n greater than or equal to m and m greater than or equal to two, to be set independently of the magnetization direction in the
10 other layers. While in the case of the single-value memories the magnetization direction is set in only one magnetic layer, in the case of the multivalue memories according to the invention, this can now be carried out in any desired number of magnetic layers. In this case,
15 the number of magnetic layers can vary depending on the requirement and application, so that the invention is not restricted to a specific number of layers. A similar multilayer system has in principle already been described in US-A-5,585,986.

20 A further fundamental feature for the memory according to the invention is that the magnetization direction in the individual layers is changed or can be changed on the basis of the electric current flowing through the
25 electric conductors.

In order to be able to set the magnetization directions in the individual magnetic layers independently of one another, it is necessary to achieve the situation where
30 the setting of the magnetization direction (remagnetization) in the individual layers is brought about at respectively different field strengths or currents in the conductors.

35 In US-A-5,585,986, this requirement is achieved by the multilayer system having a crystalline structure and by the individual layers having different crystalline symmetries and therefore magnetic anisotropies. Furthermore, the layers have a different thickness and

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layer morphology. If the multilayer system is exposed to a magnetic field with a respectively specific field strength, the magnetization direction in individual or several layers is either changed or not on the basis of
5 the field strength of the magnetic field applied and the specific configuration of the respective layer. Because of the complex manufacturing operation for the multilayer system, such a system is particularly complicated and costly.

10

With the magnetoresistive memory according to the invention, a different route is followed. This route permits the manufacture of magnetic layers with substantially identical structures and morphologies.
15 The respective, individual setting of the magnetization directions in the individual layers is brought about via respectively different field strengths by means of different current intensities. For this purpose, in each case an electric current flows through the two
20 intersecting conductors, on the basis of which current a magnetic field is in each case formed around the two conductors. The magnetic field acts on the individual magnetic layers of the multilayer system, as a result of which the latter can be remagnetized in the event of
25 adequately high field strengths. The remagnetization of individual layers therefore depends on the magnitude of the currents flowing through the two conductors and the physical arrangement of the respective magnetic layer in relation to the electric conductors.

30

The intersecting conductors into which the current producing the field is impressed therefore function as a suitable read and/or write tool for the memory. While in the case of single-value memories, a fixed current
35 is impressed into the conductors and either changes the magnetization direction in the remagnetizable magnetic layer or not, in connection with the present invention use is made of the fact that a change in the magnetic field strength is suitable to set the magnetization

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direction in a large number of magnetic layers independently of one another and individually. The provision of different magnetic field strengths can be carried out in various ways, as will be explained in
5 more detail in the further course of the description.

Advantageous embodiments of the memory according to the invention emerge from the subclaims.

10 The magnetization directions that can be set independently of one another in the individual layers can preferably be set or can be capable of being set via different current intensities. This can be carried out in different ways, depending on the configuration
15 of the storage cells. For example, it is conceivable for currents with different current intensities to be impressed into the electric conductors in order to set different magnetization directions in individual magnetic layers. As a result of the different current
20 intensities, in each case different field strengths are produced, which then lead to a change in the magnetization direction in one or more layers or not.

In a further refinement, the electric conductors can be
25 designed for high current densities.

The individual magnetic layers are preferably formed from a ferromagnetic material. However, the invention is not restricted to specific material types, so that
30 other suitable materials are also possible.

The intersecting electric conductors can advantageously be aligned orthogonally to one another.

35 In a further refinement, in each case a tunnel dielectric is provided between two adjacent magnetic layers. The electronic conductivity through such a multilayer system comprising magnetic layers and tunnel dielectric layers lying between them is substantially

determined by the tunnel effect through the tunnel dielectric. The selection of a suitable thickness for the tunnel dielectric is therefore of particular importance, since variations in the layer thickness
5 lead to considerable variations in the conductivity, since the thickness of the layer enters approximately exponentially into the tunnel current. Preferably - but not exclusively - thin tunnel dielectric layers with a thickness from 2 to 3 nanometers (nm) are therefore
10 used.

According to a second aspect of the present invention, a method of writing to a magnetoresistive read/write memory according to the invention as described above is
15 provided which, according to the invention, is characterized by the following steps: a) impressing a variable electric current into the two electric conductors and, as a result, producing a magnetic field; and b) setting the magnetization direction in
20 the individual magnetic layers of the multilayer system via the field strength of the magnetic field produced, the magnetization directions in the individual layer being set independently of one another via respectively differently high requisite field strengths, in such a
25 way that the magnetization directions are set first in those layers which need the highest field strength for the purpose, and that the magnetization directions are then set in those layers which respectively need a lower field strength for the purpose.

30 As a result of the method according to the invention, it becomes possible in a simple way to write to a multivalued magnetoresistive memory or its storage cell or storage cells. According to the invention, the
35 sequence in which the information is stored in the individual magnetic layers must be selected in such a way that the layers of a memory cell are written to in the sequence of decreasing field strength for the remagnetization of the layers (which means with

programming current intensities respectively adapted in accordance with the field strength desired on the corresponding layer). This ensures that information that has already been written to the storage cell and
5 has been written into a layer with a higher programming field strength is not overwritten again when information is written to further layers, which are then written to with respectively lower programming field strengths.

10

In relation to the advantages, reactions, effects and the functioning of the method according to the invention, reference is hereby also made further to the full disclosure of the above explanations relating to
15 the memory according to the invention. Advantageous refinements of the method according to the invention emerge from the subclaims.

The different field strengths acting on the layers can preferably be produced by currents of different magnitudes being impressed into the conductors. The different field strengths acting on the layers are further determined by a different physical spacing of the layers in relation to the electric conductors.

25

Furthermore, it is also conceivable that, for setting the magnetization directions in the layers on the basis of field strengths of different magnitudes, is influenced by characteristics of the layer material
30 and/or the layer thickness and/or the layer morphology.

Since the aforementioned examples have already been described extensively further above, reference is made at this point to the embodiments cited.

35

According to the third aspect of the present invention, a method of reading from a magnetoresistive read/write memory according to the invention as described above is provided which, according to the invention, is

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characterized by the following steps: a) impressing a defined item of data into the individual layers of the multilayer system in such a way that the item of data is first impressed into that layer which needs the
5 lowest field strength to set the magnetization direction, and that the item of data is then impressed into the layers with the respectively next higher requisite field strength; and b) detecting a possible information change in the layer or the layers on the
10 basis of the defined item of data impressed.

By means of the method according to the invention, a multivalue magnetoresistive memory can be read out in a simple way. In relation to the advantages, actions,
15 effects and the functioning of the method according to the invention, in addition to the following description, reference is hereby made to the full disclosure of the above explanations relating to the memory according to the invention and to the method
20 according to the invention for writing to a memory.

The basic idea of the method according to the invention for reading from a memory is that in each case a specific item of data, that is to say a specific item
25 of information, is written successively to the individual magnetic layers of the storage cell or of the storage cells. If the information content of the layer changes following the impression of the specific item of data, this means that the layer had previously
30 been written with a different item of information. If the information content of the layer does not change following the impression of the specific item of data, this means that the layer had previously also been written with the same item of information. In this
35 case, it is of particular importance that the item of target data is known. The item of target data is to be understood to mean that item of data which, as described above, is specifically written to the storage cell.

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The possible information change or the absence of an information change can be detected in a suitable way and then evaluated. Exemplary embodiments of this will be explained in more detail in the further course of the description.

In order to be able to carry out the action of reading from the storage cell or storage cells of the memory in an optimum way, first of all those layers are read, that is to say specifically rewritten with the specific item of data, which need the lowest programming field strength in order to set the magnetization direction. The specific item of data is therefore written to the storage cell or the individual layers of the multilayer system of the storage cell in the sequence of increasing programming field strength.

Advantageous embodiments of the method according to the invention emerge from the subclaims.

The possible information change in the layer or the layers can preferably be discovered by measuring the electrical resistance. Since the electrical resistance of the storage cell depends on the magnetization directions (parallel or antiparallel) of the individual layers, and the magnetization directions can change on the basis of possible information changes, a change in the electric resistance means that the information content of the storage cell or of individual layers of the memory cell has changed.

In addition, the possible information change in the layer or the layers can be carried out via detection of current and/or voltage pulses. If the action of writing the specific item of data to the layers of the storage line leads to an information change, a current and/or voltage pulse also occurs in the process, and can be detected. For the case in which no current and/or voltage pulse is detected, this means that no

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information change has taken place either in the layer or the layers.

5 The detection of a possible information change in the layer or the layers can preferably be carried out before and after the impression and/or during the impression of the specific item of data into the layer or the layers.

10 In an advantageous refinement, a specific item of data with respectively the same value can be impressed successively into all the layers. If information in binary form, that is to say with logic values "1" and "0", is stored in the storage cells, the specific item
15 of data which is written successively to all the layers of the storage cell can have either the logic value "1" or "0".

In another refinement, it is also conceivable for an
20 item of data which belongs to an alternating algorithm to be impressed successively into the layers.

The results during the detection of a possible information change for each layer can advantageously be
25 stored intermediately, at least temporarily, in a suitable storage device.

The invention will now be explained in more detail using exemplary embodiments and with reference to the
30 appended drawing, in which:

Fig. 1a shows a schematic perspective view of a magnetoresistive storage cell according to the prior art;

35

Fig. 1b shows a schematic cross-sectional view of the storage cell according to Fig. 1a;

Fig. 1c shows an equivalent circuit for a storage cell according to Fig. 1a;

5 Fig. 2 shows a schematic cross-sectional view of a first embodiment of a multivalue memory cell according to the invention, a two-value memory cell here, different magnetization states being illustrated in the partial views a) to d); and

10 Fig. 3 shows a cross-sectional view of another embodiment of the multivalue storage cell according to the invention.

Figs. 1a to 1c show a storage cell 11 of a
15 magnetoresistive memory 10 according to the prior art. The storage cell 11 is designed as a single-value storage cell and has an upper 12 and a lower 13 electric conductor, which are aligned orthogonally to each other and intersect at an intersection of the
20 storage cell 11. At the intersection there is a layer system 14 with two magnetic layers, a hard magnetic layer 15 and a soft magnetic layer 16. Between the layers 15, 16 there is a tunnel dielectric 20. For the storage cell 11, an equivalent circuit according to
25 Fig. 1c can be specified, the value of the resistance 19 contained therein between the conductors 12, 13 depending on whether the magnetization directions 17, 18 in the magnetic layers 15, 16 are in parallel or antiparallel. The example according to Fig. 1b shows an
30 antiparallel alignment of the magnetization directions. A parallel magnetization direction leads to a lower resistance value, while an antiparallel magnetization direction leads to a higher resistance value.

35 In order to write to the storage cell 11, high electric currents are impressed simultaneously into the conductors 12, 13. The magnetic field generated by these currents at the intersection of the conductors

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12, 13 has an adequately high field strength there for the remagnetization of the soft magnetic layer 16.

5 The storage cell 11 and the memory 10 formed from one or more such storage cells 11 need a relatively large area.

10 In order to circumvent this disadvantage, a multivalued memory having multivalued storage cells is proposed. Two exemplary embodiments of such storage cells according to the invention are described in figs. 2 and 3.

15 Fig. 2 shows in schematic form a two-layer 2-bit storage cell 11, as it is known. Between the two electric conductors 12, 13, at their intersection, there is a multilayer system 30 with a plurality of magnetic layers 31, 32 and tunnel dielectrics 35 in each case arranged between them.

20 In principle, the multilayer system has n magnetic layers, the condition $n \geq 2$ applying. Of these n layers, the magnetization direction can be set in m layers independently of the other adjacent layers, it being true that: $n \geq m \geq 2$.

25 In the exemplary embodiment according to fig. 2, two magnetic layers 31, 32 are illustrated, whose magnetization directions 33, 34 can in each case be set independently of one another. The part views 2a to 2d of fig. 2 in this case show the different possible magnetization states or magnetization directions 33, 34 in the magnetic layers 31, 32.

35 For the following explanation of the information content of the storage cell 11, the nomenclature introduced will be to name the magnetization directions with corresponding reference numbers, such as logic "0" and logic "1", the magnetization directions being described with increasing magnitude of the reference

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numbers for the magnetic layers counted from top to bottom. Logic "0" stands for the magnetization direction "from left to right" shown in figs. 2 and 3, logic "1" stands for the magnetization direction "from
5 right to left" shown in figs. 2 and 3.

According to fig. 2 and the part views shown therein, a total of four different magnetization states can be set in the magnetic layers 31, 32. According to fig. 2a, in
10 accordance with the nomenclature introduced above, a logic "0" applies to the set magnetization direction 33, while a logic "0" likewise applies to the magnetization direction 34. According to Fig. 2b, the result is 33 = "0" and 34 = "1". fig. 2 shows the
15 magnetization state 33 = "1" and 34 = "0", while fig. 2d shows the magnetization state 33 = "1" and 34 = "1".

A further exemplary embodiment of a storage cell 11 is
20 shown in fig. 3. The storage cell 11 again has two intersecting electric conductors 12, 13 and a multilayer system 40 which is located at the intersection of the conductors 12, 13 and in the present case is formed of five magnetic layers 40-45,
25 in which the respective magnetization directions 46-50 can in each case be set independently of adjacent layers. There is in each case a tunnel dielectric 51 between the magnetic layers.

30 According to the nomenclature introduced above, the storage cell 11 according to fig. 3 has the following magnetization state: layer 41 has a magnetization direction 46 with logic "0", layer 42 has a magnetization direction 47 with logic "1", layer 43 has
35 a magnetization direction 48 with logic "1", layer 44 has a magnetization direction 49 with logic "0" and layer 45 has a magnetization direction 50 with logic "1".

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In order to be able to write specifically to the storage cells 11 explained above, the various magnetic layers 31, 32 or 41-45 must satisfy the requirement that different current intensities in the field-producing conductors 12, 13 are needed for their remagnetization. This can be achieved by respectively different magnetic field strengths being required in the individual layers. In this case, currents of different magnitudes can be impressed into the conductors 12, 13 and then produce the different field strengths for the remagnetization of the individual layers. At the same time, in order to provide field strengths of different magnitudes to set the magnetization directions in the individual layers, use is also made of the different physical spacing between the layer respectively to be remagnetized and the conductors 12, 13.

The sequence of storing the information in the individual layers 31, 32 or 41-45 of the storage cell 11 must be selected such that the layers of the storage cell are written to in the sequence of decreasing programming field strength. This means that first of all those layers which need the highest field strength to set the magnetization direction are written to first, while those layers which respectively need a lower field strength for this purpose are subsequently written to. This ensures that information that has already been written into the storage cell 11 and initially was written into a layer with a higher programming field strength cannot be overwritten again when information is being written into further layers.

For the reading procedure, according to the invention a method is specified which, for example, is based on the direct measurement of the resistance or on the detection of current and/or voltage pulses when a defined item of information is impressed into the corresponding bit of the storage cell 11 to be read.

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The information content of the storage cells 11 is in principle changed during the complete read operation. However, no additional reference storage cell is needed.

5

The reading method will now be described by way of example using an m-bit cell, which is designed as a 2-bit cell. This cell has exactly m (with $m = 2$) remagnetizable layers, each of which has a magnetization direction MR_k , MR_k describing the magnetization direction of the kth magnetic layer, counted from top to bottom, where $1 \leq k \leq m$. The storage cell contains the data D_k present in binary form, where $1 \leq k \leq m$. In order to read from this cell, a defined item of data $E_k = E_{fix}$, where $1 \leq k \leq m$, is written to this cell in the sequence of increasing programming field strength (first of all, therefore, into those layers which need a low field strength in order to set the magnetization direction). For example, for all k, this item of data can have the logic value "0" or "1".

Before the start of this read operation, it is therefore true that $MR_k = D_k$, and after it has been concluded, $MR_k = E_{fix}$, for all layers k with $1 \leq k \leq m$.

For the case in which a current and/or voltage pulse is detected during the kth write operation, this is a positive indicator that a change has taken place in the corresponding kth item of data, that is to say it is true that $D_k =$ the item of data that is the complement of E_{fix} . Before the defined item of data E_{fix} was read into the layer, the latter therefore had stored the item of data that was the complement of E_{fix} . For the case in which no current and/or voltage pulse is detected, it is true that $D_k = E_{fix}$. Thus, after the read operation has been completed, the complete binary data from the storage cell is available.

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As an alternative to the detection of a current and/or voltage pulse, a measurement of the electrical resistance in each case before and after the impression of the defined item of data Efix into the corresponding bit can also be performed for each write operation. In the case of an m-bit cell, a 2-bit cell in the present case, this means that a total of m+1 measurements, three measurements in the present case, have to be performed. The individual measured values for each layer are intermediately stored, at least temporarily, in a suitable storage device. For the case in which, during the measurements relating to the kth bit, the resistance values before and after the impression of the item of data Efix are different, it is true that Dk before the impression of the item of data Efix was originally the item of data that is the complement of Efix. In the case of identical resistance values before and after the impression of the item of data Efix, the result is $D_k = E_{fix}$.

The reading method cited above was used to read out 2-bit cells. However, similar methods are also possible for m-bit cells with $m > 2$.

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Patent Claims

1. A magnetoresistive read/write memory, with a plurality of multivalue storage cells (11), each storage cell (11) having two intersecting electric conductors (12, 13) and a layer system comprising magnetic layers located at the intersection of the electric conductors (12, 13), wherein the layer system is designed as a multilayer system (30; 40) with two or more magnetic layers (31, 32; 41-45), at least two, but a maximum of all the magnetic layers (31, 32; 41-45) have a magnetization direction (33, 34; 46-50) that can be set independently of one another, the magnetization direction (33, 34; 46-50) in the individual layers (31, 32; 41-45) is changed or can be changed by the electric current flowing through the electric conductors (12, 13), in each case a tunnel dielectric (35; 51) is provided between two adjacent magnetic layers (31, 32; 41-46).
2. The magnetoresistive read/write memory as claimed in claim 1, in which the magnetization directions (33, 34; 46-50) that can be set independently of one another in the individual layers (31, 32; 41-45) are set or can be set via different current intensities.
3. The magnetoresistive read/write memory as claimed in claim 1 or 2, in which the electric conductors (12, 13) are designed for high current densities.
4. The magnetoresistive read/write memory as claimed in one of claims 1 to 3, in which the magnetic layers (31, 32; 41-45) are formed from a ferromagnetic material.
5. The magnetoresistive read/write memory as claimed in one of claims 1 to 4, in which the intersecting

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conductors (12, 13) are aligned orthogonally to one another.

6. The magnetoresistive read/write memory as claimed
5 in one of claims 1 to 5, in which the tunnel dielectric has a thickness of 2 to 3 nm.

7. A method of writing to a magnetoresistive
10 read/write memory as claimed in one of claims 1 to 6, having the following steps:

a) impressing a variable electric current into the two electric conductors and, as a result, producing a magnetic field;

b) setting the magnetization direction in the
15 individual magnetic layers of the multilayer system via the field strength of the magnetic field produced, the magnetization directions in the individual layers being set independently of one another via respectively differently high requisite field strengths, in such a
20 way that the magnetization directions are set first in those layers which need the highest field strength for this purpose and that the magnetization directions are then set in those layers which respectively need a lower field strength for this purpose.

25

8. The method as claimed in claim 7, in which the different field strengths acting on the layers are produced by currents of different magnitudes being impressed into the conductors.

30

9. The method as claimed in claim 7 or 8, in which the different field strengths acting on the layers are produced by means of a different physical spacing of the layers in relation to the conductors.

35

10. The method as claimed in one of claims 7 to 9, in which the setting of the magnetization directions in the layers on the basis of field strengths of different

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magnitudes are influenced by the layer material and/or the layer thickness and/or the layer morphology.

11. A method of reading from a magnetoresistive
5 read/write memory as claimed in one of claims 1 to 6, having the following steps:

- a) impressing a defined item of data into the individual layers of the multilayer system in such a way that the item of data is first impressed into that
10 layer which needs the lowest field strength to set the magnetization direction, and that the item of data is then impressed into the layers having the respectively next higher requisite field strength; and
b) detecting a possible information change in the layer
15 or the layers on the basis of the impressed defined item of data.

12. The method as claimed in claim 11, in which the detection of a possible information change in the layer
20 or the layers is carried out by measuring the electrical resistance.

13. The method as claimed in claim 11 or 12, in which the detection of a possible information change in the
25 layer or the layers is carried out via detection of current and/or voltage pulses.

14. The method as claimed in one of claims 11 to 13, in which the detection of a possible information change
30 in the layer or the layers is carried out before and after the impression and/or during the impression of the specific item of data into the layer or the layers.

15. The method as claimed in one of claims 11 to 14,
35 in which an item of data with respectively the same value is successively impressed into all the layers.

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16. The method as claimed in one of claims 11 to 14, in which an item of data which belongs to an alternating algorithm is impressed successively into the layers.

5

17. The method as claimed in one of claims 11 to 16, in which the results during the detection of a possible information change for each layer are intermediately stored, at least temporarily, in a storage device.

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(19) Weltorganisation für geistiges Eigentum
Internationales Büro



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5. April 2001 (05.04.2001)

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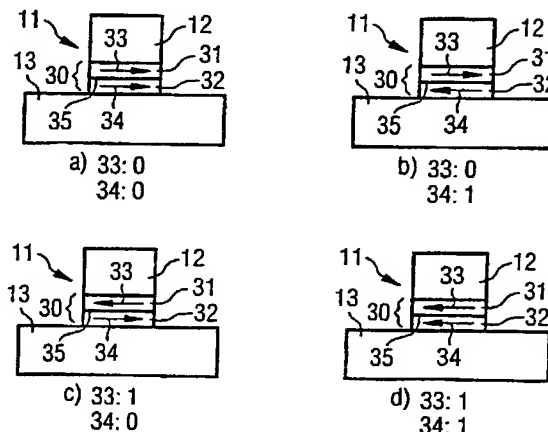
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— Mit internationalem Recherchenbericht.

[Fortsetzung auf der nächsten Seite]

(54) Title: POLYVALENT, MAGNETORESISTIVE WRITE/READ MEMORY AND METHOD FOR WRITING AND READING A MEMORY OF THIS TYPE

(54) Bezeichnung: MEHRWERTIGER MAGNETORESISTIVER SCHREIB/LESE-SPEICHER SOWIE VERFAHREN ZUM BESCHREIBEN UND AUSLESEN EINES SOLCHEN SPEICHERS



(57) Abstract: The invention relates to a polyvalent, magnetoresistive write/read memory (10). Said memory (10) has one or more memory cells (11), whereby each memory cell (11) has two electric conductors (12, 13) which intersect, in addition to a layer system consisting of magnetic layers which is located at the intersection point of the electric conductors (12, 13). In order to create a polyvalent memory (10) with a corresponding memory capacity and optimal write and read characteristics, the invention is characterised in that the layer system is configured as a multi-layer system (30), comprising two or more magnetic layers (31, 32) and tunnel dielectric layers (35) positioned therebetween, that at least two and at maximum all the magnetic layers (31, 32) have a magnetization direction (33, 34) which can be set independently of the layers and that the magnetization direction (33, 34) in the individual layers (31, 32) can be changed or is changed by means of the electric current which flows through the electric conductors (12, 13). The invention also relates to a method for writing and for reading a memory (10) of this type.

[Fortsetzung auf der nächsten Seite]

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FIG 1A

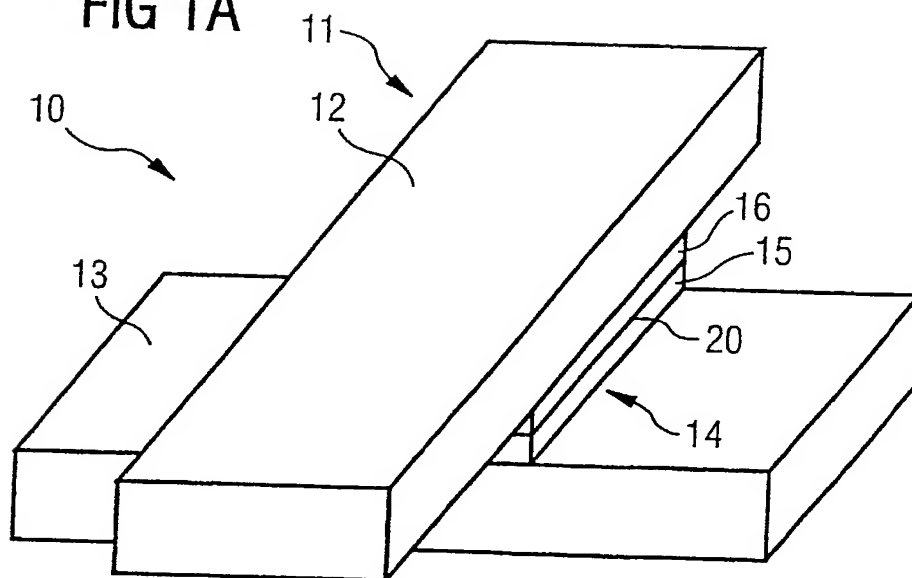


FIG 1B

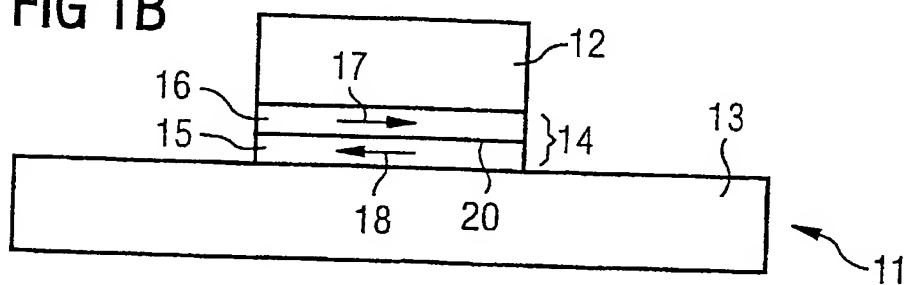
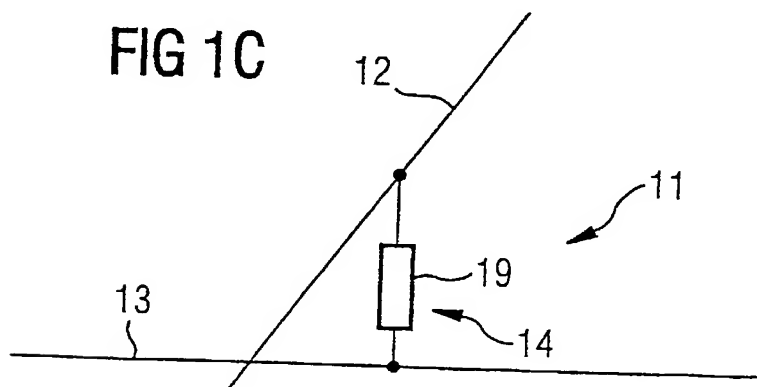
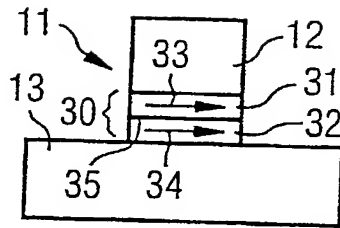


FIG 1C

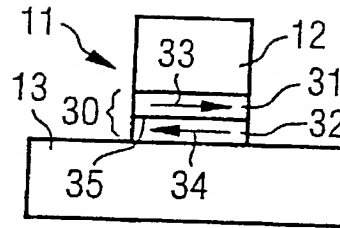


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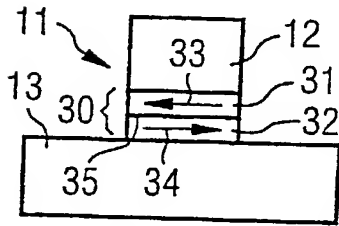
FIG 2



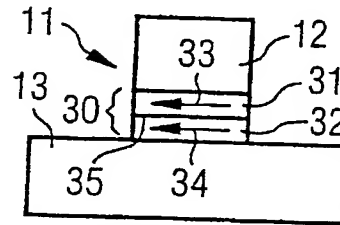
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34: 0



b) 33: 0
34: 1

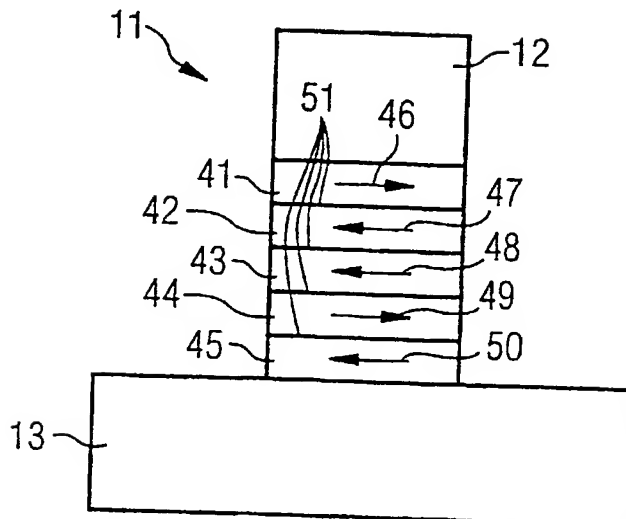


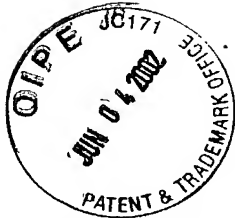
c) 33: 1
34: 0



d) 33: 1
34: 1

FIG 3





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I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Mehrwertiger Magnetoresistiver Schreib/Lese-Speicher sowie

Verfahren zum Beschreiben eines Solchen Speichers

the specification of which is attached hereto unless the following box is checked:

- ☒ was filed on March 27, 2002
as United States Application Number or PCT
International Application Number 10/089531
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_____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

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[Page 1 of 3]

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PCT/DE00/03293 September 21, 2000
(Application No.) (Filing Date)
(Aktenzeichen) (Anmeldetag)

(Application No.) (Filing Date)
(Aktenzeichen) (Anmeldetag)

Ich erkläre hiermit, daß alle in der vorliegenden Erklärung von mir gemachten Angaben nach bestem Wissen und Gewissen der Wahrheit entsprechen, und ferner daß ich diese eidesstattliche Erklärung in Kenntnis dessen ablege, daß wissentlich und vorsätzlich falsche Angaben oder dergleichen gemäß § 1001, Title 18 des US-Code strafbar sind und mit Geldstrafe und/oder Gefängnis bestraft werden können und daß derartige wissentlich und vorsätzlich falsche Angaben die Rechtswirksamkeit der vorliegenden Patentanmeldung oder eines aufgrund deren erteilten Patentes gefährden können

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Priority Not Claimed
Priorität nicht beansprucht

28 September 1999
(Day/Month/Year Filed)
(Tag/Monat/Jahr der Anmeldung)

☐

(Day/Month/Year Filed)
(Tag/Monat/Jahr der Anmeldung)

☐

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(Status) (patented, pending, abandoned)
(Status) (patentiert, schwebend, aufgegeben)

(Status) (patented, pending, abandoned)
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon

German Language Declaration

VERTRETUNGSVOLMACHT: Als benannter Erfinder beauftrage ich hiermit den (die) nachstehend aufgeführten Patentanwalt (Patentanwälte) und/oder Vertreter mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Angelegenheiten vor dem US-Patent- und Markenamt: (Name(n) und Registrationsnummer(n) auflisten)

Postanschrift:

Telefonische Auskünfte. (Name und Telefonnummer)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: (list name and registration number)

Gerald E. Helget - #30,948
Nelson R. Capes - #37,106
Kevin W. Cyr - #40,976
Kurt J. Niederluecke - #40,102
Jeffrey R. Stone - #47,976

Send Correspondence to:

Jeffrey R. Stone
BRIGGS AND MORGAN
2200 First National Bank Building
332 Minnesota Street
St. Paul, MN 55101

(651) 223-6600 (Attorney Docket No. 32226.19)

Direct Telephone Calls to: (name and telephone number)

Jeffrey R. Stone (651) 223-6600

Vor- und Zuname des einzigen oder ersten Erfinders	Full name of sole or first inventor	Thewes, Roland
Unterschrift des Erfinders	Datum	Inventor's signature Date
Wohnsitz	Residence Jagerheimstr. 7, 82194 Grobenzell, Deutschland	
Staatsangehörigkeit	Citizenship Germany	
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of second joint inventor, if any	Weber, Werner
Unterschrift des zweiten Erfinder	Datum	Second Inventor's signature Date
Wohnsitz	Residence Franz-Marc-Str. 6, 80637 Munchen, Deutschland	
Staatsangehörigkeit	Citizenship Germany	
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of third joint inventor, if any	Schwarzl, Siegfried
Unterschrift des zweiten Erfinder	Datum	Third Inventor's signature Date May 10, 2002
Wohnsitz	Residence Josef-Kyreim-Str. 11 d, 85579 Neubiberg, Deutschland	
Staatsangehörigkeit	Citizenship Germany	

Postanschrift	Post Office Address
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PTO/SB/103 (8-96)

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Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Declaration and Power of Attorney for Patent Application Erklärung für Patentanmeldungen mit Vollmacht

German Language Declaration

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daß mein Wohnsitz, meine Postanschrift und meine Staatsangehörigkeit den im nachstehenden nach meinem Namen aufgeführten Angaben entsprechen, daß ich nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent für die Erfindung mit folgendem Titel beantragt wird:

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- ☐ wurde angemeldet am _____ unter der US-Anmeldenummer oder unter der Internationalen Anmeldenummer im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT) _____ und am _____ abgeändert (falls zutreffend).

Ich bestätige hiermit, daß ich den Inhalt der oben angegebenen Patentanmeldung, einschließlich der Ansprüche, die eventuell durch einen oben erwähnten Zusatzantrag abgeändert wurde, durchgesehen und verstanden habe

Ich erkenne meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Titel 37, Code of Federal Regulations, § 1.56 von Belang sind.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Mehrwertiger Magnetoresistiver Schreib/Lese-Speicher sowie

Verfahren zum Beschreiben eines Solchen Speichers

the specification of which is attached heretounless the following box is checked:

- ☒ was filed on March 27, 2002
as United States Application Number or PCT
International Application Number 10/089531
_____ and was amended on
_____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

[Page 1 of 3]

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Robert A. Yard

(Type or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

German Language Declaration

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäß Title 35, United States Code, § 119 (a)-(d), bzw. § 365(b) aller unten aufgeführten Auslandsanmeldungen für Patente oder Erfinderurkunden, oder § 365(a) aller PCT internationalen Anmeldungen, welche wenigstens ein Land ausser den Vereinigten Staaten von Amerika benennen, und habe nachstehend durch ankreuzen sämtliche Auslandsanmeldungen für Patente bzw. Erfinderurkunden oder PCT internationale Anmeldungen angegeben, deren Anmeldetag dem der Anmeldung, für welche Priorität beansprucht wird, vorangeht

Prior Foreign Applications
(Frühere ausländische Anmeldungen)

19946490.1 Germany
(Number) (Country)
(Nummer) (Land)

____ (Country)
(Number) (Land)

Ich beanspruche hiermit Prioritätsvorteile unter Title 35, US-Code, § 119(e) aller US-Hilfsanmeldungen wie unten aufgezählt.

____ (Filing Date)
(Application No.) (Anmeldetag)
(Aktenzeichen)

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(Application No.) (Anmeldetag)
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Ich beanspruche hiermit die mir unter Title 35, US-Code, § 120 zustehenden Vorteile aller unten aufgeführten US-Patentanmeldungen bzw. § 365(c) aller PCT internationalen Anmeldungen, welche die Vereinigten Staaten von Amerika benennen, und erkenne, insofern der Gegenstand eines jeden früheren Anspruchs dieser Patentanmeldung nicht in einer US-Patentanmeldung, bzw. PCT internationalen Anmeldung in in einer gemäß dem ersten Absatz von Title 35, US-Code, § 112 vorgeschriebenen Art und Weise offenbart wurde, meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Title 37, Code of Federal Regulations, § 1.56 von Belang sind und die im Zeitraum zwischen dem Anmeldetag der früheren Patentanmeldung und dem nationalen oder im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT) gültigen internationalen Anmeldetags bekannt geworden sind

PCT/DE00/03293 September 21, 2000
(Application No.) (Filing Date)
(Aktenzeichen) (Anmeldetag)

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Ich erkläre hiermit, daß alle in der vorliegenden Erklärung von mir gemachten Angaben nach bestem Wissen und Gewissen der Wahrheit entsprechen, und ferner daß ich diese eidesstattliche Erklärung in Kenntnis dessen ablege, daß wissentlich und vorsätzlich falsche Angaben oder dergleichen gemäß § 1001, Title 18 des US-Code strafbar sind und mit Geldstrafe und/oder Gefängnis bestraft werden können und daß derartige wissentlich und vorsätzlich falsche Angaben die Rechtswirksamkeit der vorliegenden Patentanmeldung oder eines aufgrund deren erteilten Patentes gefährden können.

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Priorität nicht beansprucht

28 September 1999
(Day/Month/Year Filed)
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☐

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(651) 223-6600 (Attorney Docket No. 32226.19)

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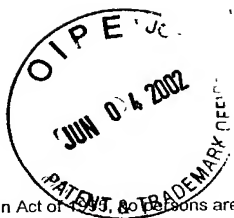
Vor- und Zuname des einzigen oder ersten Erfinders	Full name of sole or first inventor	Thewes, Roland
Unterschrift des Erfinders	Inventor's signature	
Datum	Date	
Wohnsitz	Residence	Jagerheimstr. 7, 82194 Grobenzell, Deutschland
Staatsangehörigkeit	Citizenship	Germany
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of second joint inventor, if any	Weber, Werner
Unterschrift des zweiten Erfinder	Second Inventor's signature	
Datum	Date	May 10, 2002
Wohnsitz	Residence	Franz-Marc-Str. 6, 80637 Munchen, Deutschland
Staatsangehörigkeit	Citizenship	Germany
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of third joint inventor, if any	Schwarzl, Siegfried
Unterschrift des zweiten Erfinder	Third Inventor's signature	
Datum	Date	
Wohnsitz	Residence	Josef-Kyreim-Str. 11 d, 85579 Neubiberg, Deutschland
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Verfahren zum Beschreiben eines Solchen Speichers

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- ☒ was filed on March 27, 2002 as United States Application Number or PCT International Application Number 10/089531 and was amended on _____ (if applicable).

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I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56

[Page 1 of 3]

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Roberto A. Yord
(Typed or printed name of person mailing paper or fee)
Roberto A. Yord
(Signature of person mailing paper or fee)

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Prior Foreign Applications
(Frühere ausländische Anmeldungen)

19946490_1 Germany
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PCT/DE00/03293 September 21, 2000
(Application No.) (Filing Date)
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Priority Not Claimed
Priorität nicht beansprucht

28 September 1999
(Day/Month/Year Filed)
(Tag/Monat/Jahr der Anmeldung)

☐

____ (Day/Month/Year Filed)
(Tag/Monat/Jahr der Anmeldung)

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____ (Status) (patented, pending, abandoned)
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Postanschrift:

Telefonische Auskünfte: (Name und Telefonnummer)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: (list name and registration number)

Gerald E. Helget - #30,946
Nelson R. Capes - #37,406
Kevin W. Cyr - #40,976
Kurt J. Niederluecke - #40,102
Jeffrey R. Stone - #47,976

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BRIGGS AND MORGAN
2200 First National Bank Building
332 Minnesota Street
St. Paul, MN 55101

(651) 223-6600 (Attorney Docket No. 32226.19)

Direct Telephone Calls to: (name and telephone number)

Jeffrey R. Stone (651) 223-6600

Vor- und Zuname des einzigen oder ersten Erfinders	Full name of sole or first inventor	Thewes, Roland
Unterschrift des Erfinders	Inventor's signature	<i>Roland Thewes</i>
Datum	Date	May 17, 2002
Wohnsitz	Residence	Jagerheimstr. 7, 82194 Grobenzell, Deutschland
Staatsangehörigkeit	Citizenship	Germany
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of second joint inventor, if any	Weber, Werner
Unterschrift des zweiten Erfinder	Second Inventor's signature	
Datum	Date	
Wohnsitz	Residence	Franz-Marc-Str. 6, 80637 Munchen, Deutschland
Staatsangehörigkeit	Citizenship	Germany
Postanschrift	Post Office Address	
Vor- und Zuname des zweiten Miterfinders (falls zutreffend)	Full name of third joint inventor, if any	Schwarzl, Siegfried
Unterschrift des zweiten Erfinder	Third Inventor's signature	
Datum	Date	
Wohnsitz	Residence	Josef-Kyreim-Str. 11 d, 85579 Neubiberg, Deutschland
Staatsangehörigkeit	Citizenship	Germany

10063531 060402

03/04/02

Postanschrift	Post Office Address
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(Im Falle dritter und weiterer Miterfinder sind die entsprechenden Informationen und Unterschriften hinzuzufügen.)

(Supply similar information and signature for third and subsequent joint inventors.)

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